

Sixth Annual Conference on Carbon Capture & Sequestration

THE IMPORTANCE OF RESERVOIR ARCHITECTURE IN ENCOURAGING PLUME IMMOBILIZATION AND ENHANCING STORAGE CAPACITY

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May 7-10, 2007 • Sheraton Station Square • Pittsburgh, Pennsylvania

Presentation Outline

- Study Background
- Site Geology
- Results and Discussion
- Conclusions

Background

Because of its natural buoyancy, injected CO₂ tends to migrate to the crest of a saline reservoir and rapidly migrate outward, resulting in :

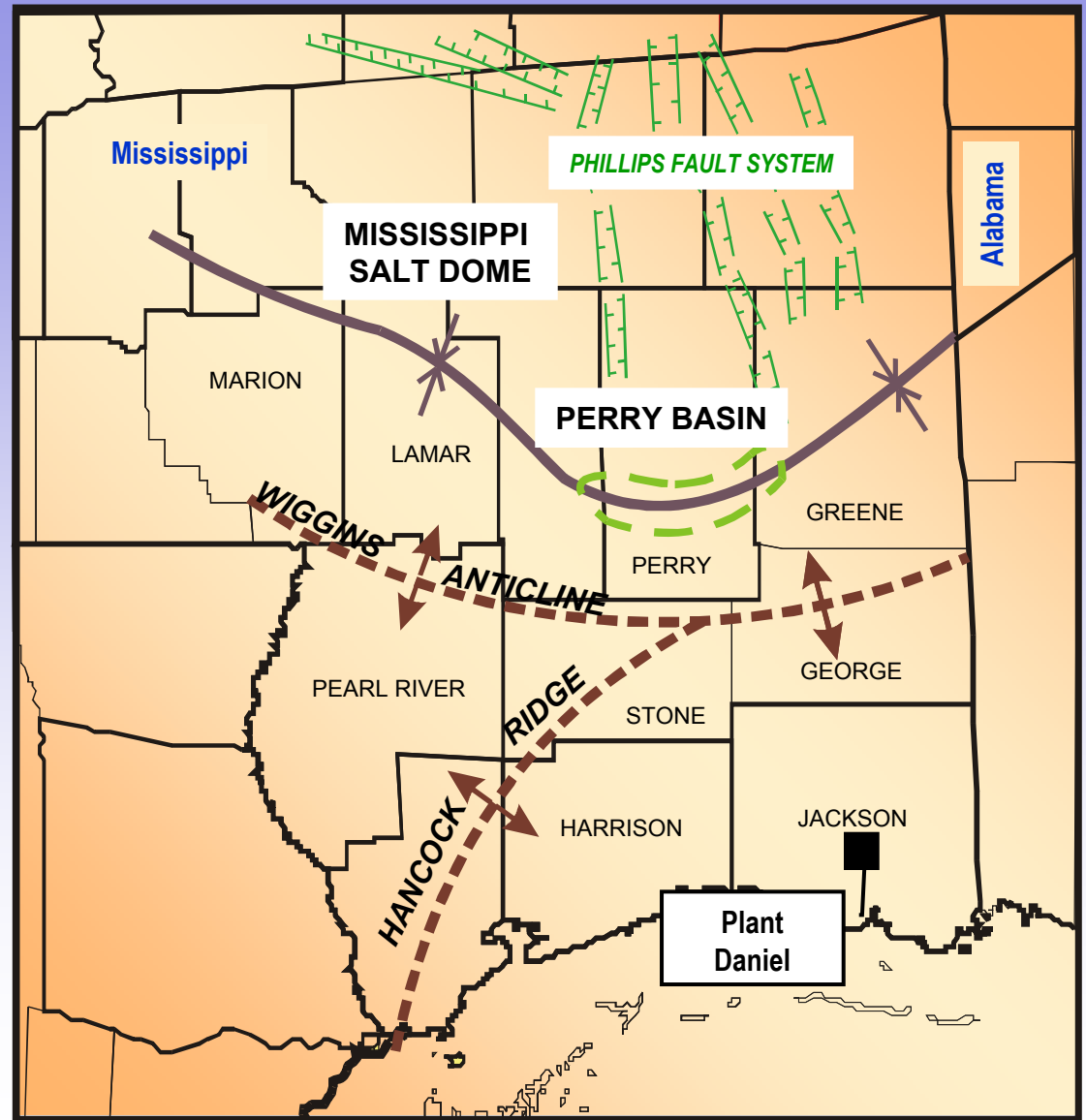
- Limited practical storage capacity
- Increased time until immobilization
- Increased horizontal plume migration

This study explores the impact of a reservoir's internal structure, or “architecture”, on these effects. This study uses reservoir simulation of CO₂ injection into the Lower Tuscaloosa Formation at the SECARB Saline Reservoir Test Site in Mississippi as the field example.

Plant Daniel Test Site

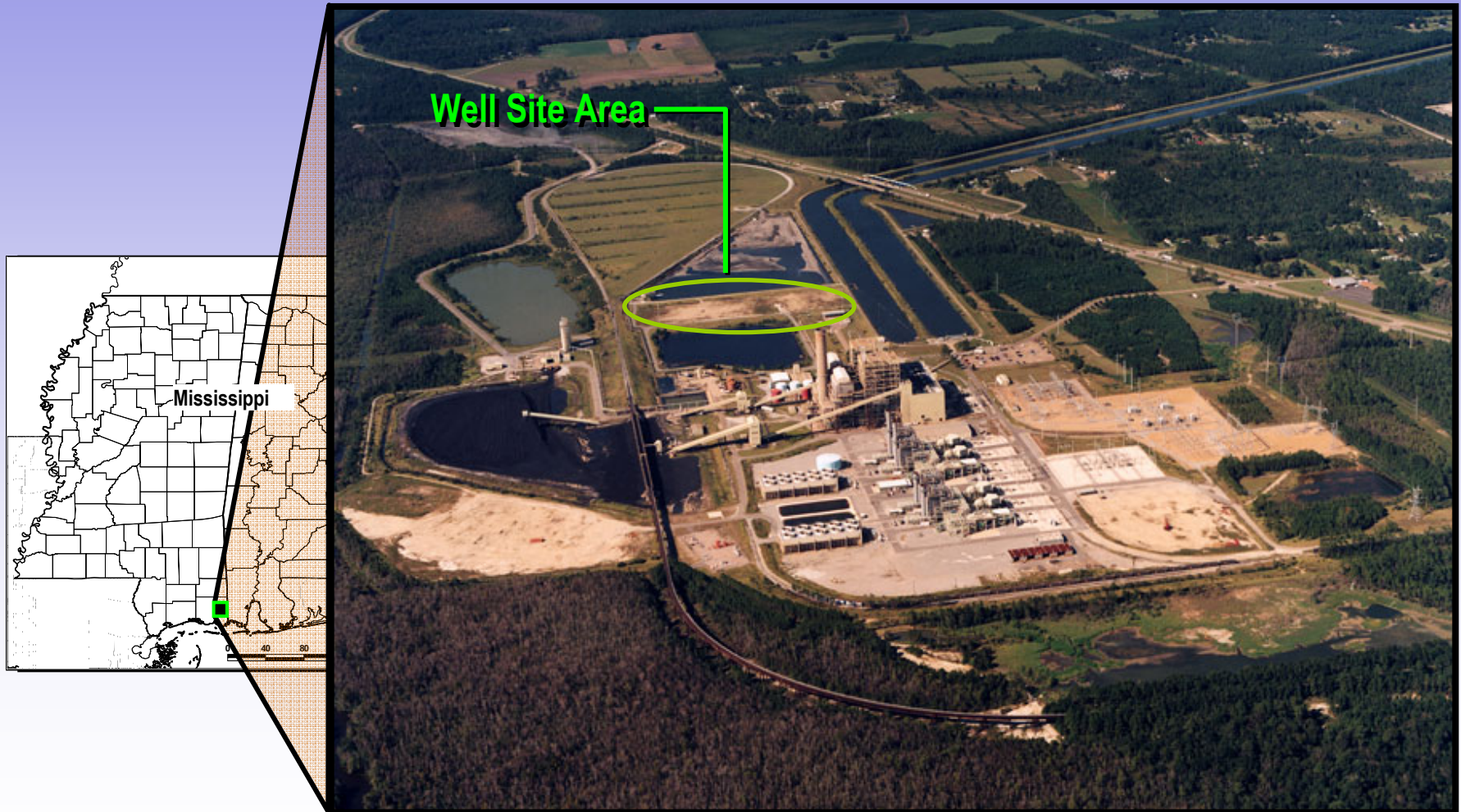
The site evaluation process found the Lower Tuscaloosa Formation below Southern Company's Plant Daniel along the Mississippi Gulf Coast to be a safe, secure CO₂ storage site and formation:

- Competent, regionally extensive caprock and seal(s)
- Multiple shallower "safety zones"
- Updip structural confinement
- High CO₂ storage capacity with favorable reservoir properties
- Favorable hydrological system
- Protection of potable and low salinity water



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Location: Mississippi Power Company's Victor J. Daniel Power Plant



Saline Reservoir Units and Seals (SE Mississippi)

Potential CO₂ Storage Units

- Lower Tuscaloosa Massive Sand Unit (U. Cretaceous)
- Dantzler Formation (L. Cretaceous)

Confining Units (Seals):

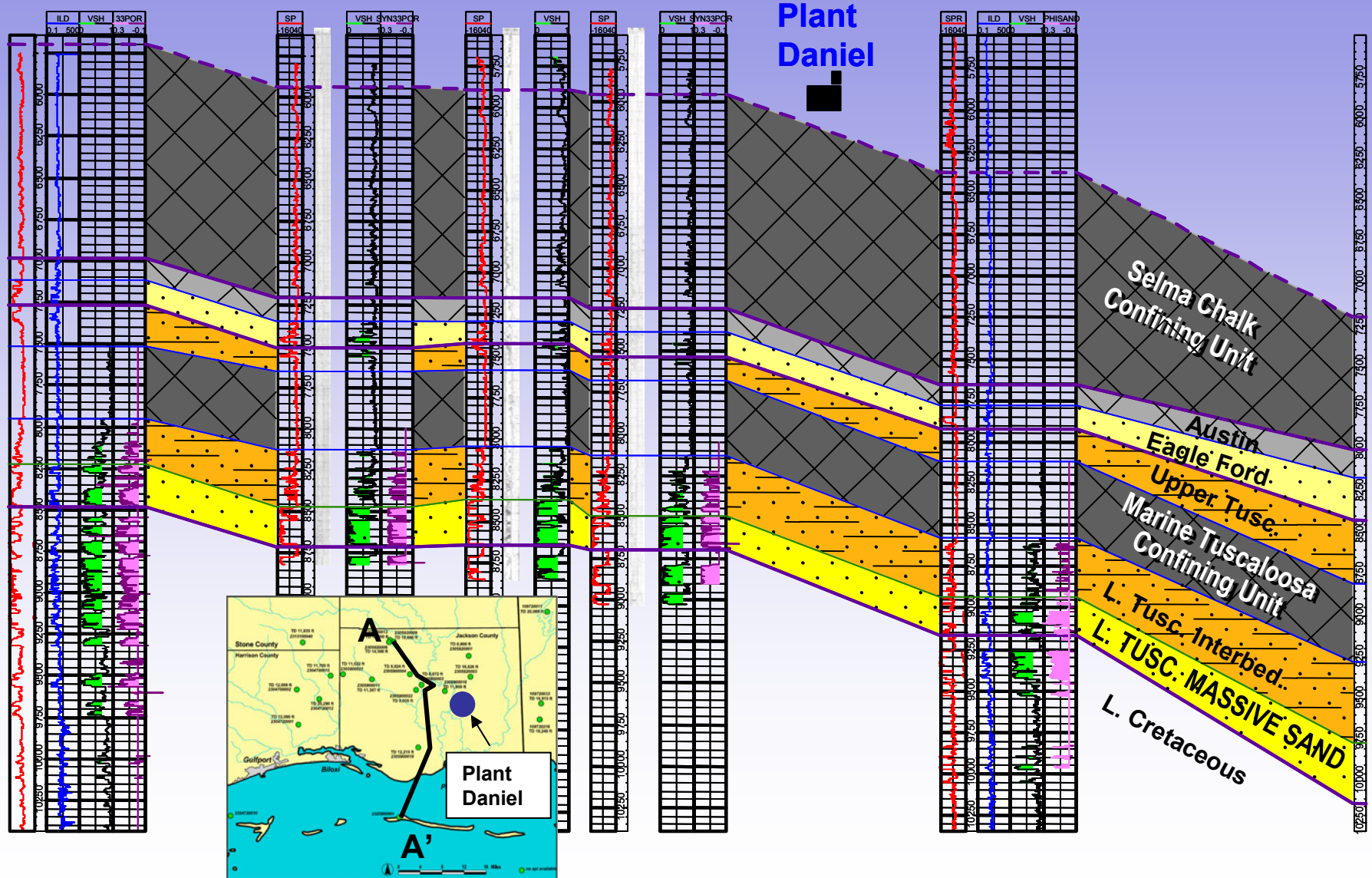
- Marine Tuscaloosa
- Austin Formation
- Selma Chalk/Navarro Fm.
- Midway Shale

System	Series	Stratigraphic Unit	Sub-Units	Hydrology	
Tertiary	Pliocene		Citronelle Fm.	Freshwater Aquifers	
			Graham Ferry Fm.		
	Miocene	Misc. Miocene Units	Pascagoula Fm.	Freshwater Aquifers	
			Hattiesburg Fm.		
			Catahoula Fm.		
	Oligocene	Vicksburg		Saline Reservoir	
			Red Bluff Fm.	Minor Reservoir	
	Eocene	Jackson		Saline Reservoir	
		Claiborne		Saline Reservoir	
		Wilcox		Saline Reservoir	
Paleocene	Midway Shale		Confining unit		
Cretaceous	Upper	Selma Chalk	Navarro Fm.	Confining unit	Additional Confining Zone
			Taylor Fm.		
		Eutaw	Austin Fm.	Confining unit	
			Eagle Ford Fm.	Saline Reservoir	
		Tuscaloosa Group	Upper Tusc.	Minor Reservoir	Confining Zone
			Marine Tusc.	Confining unit	
			Lower Tusc.	Interbeds	Saline Reservoir
		Massive Sand			
	Lower	Washita – Fredricksburg	Dantzler Fm.	Saline Reservoir	
			“Limestone Unit”		

North-South Geologic Cross Section

A(N)

A'(S)

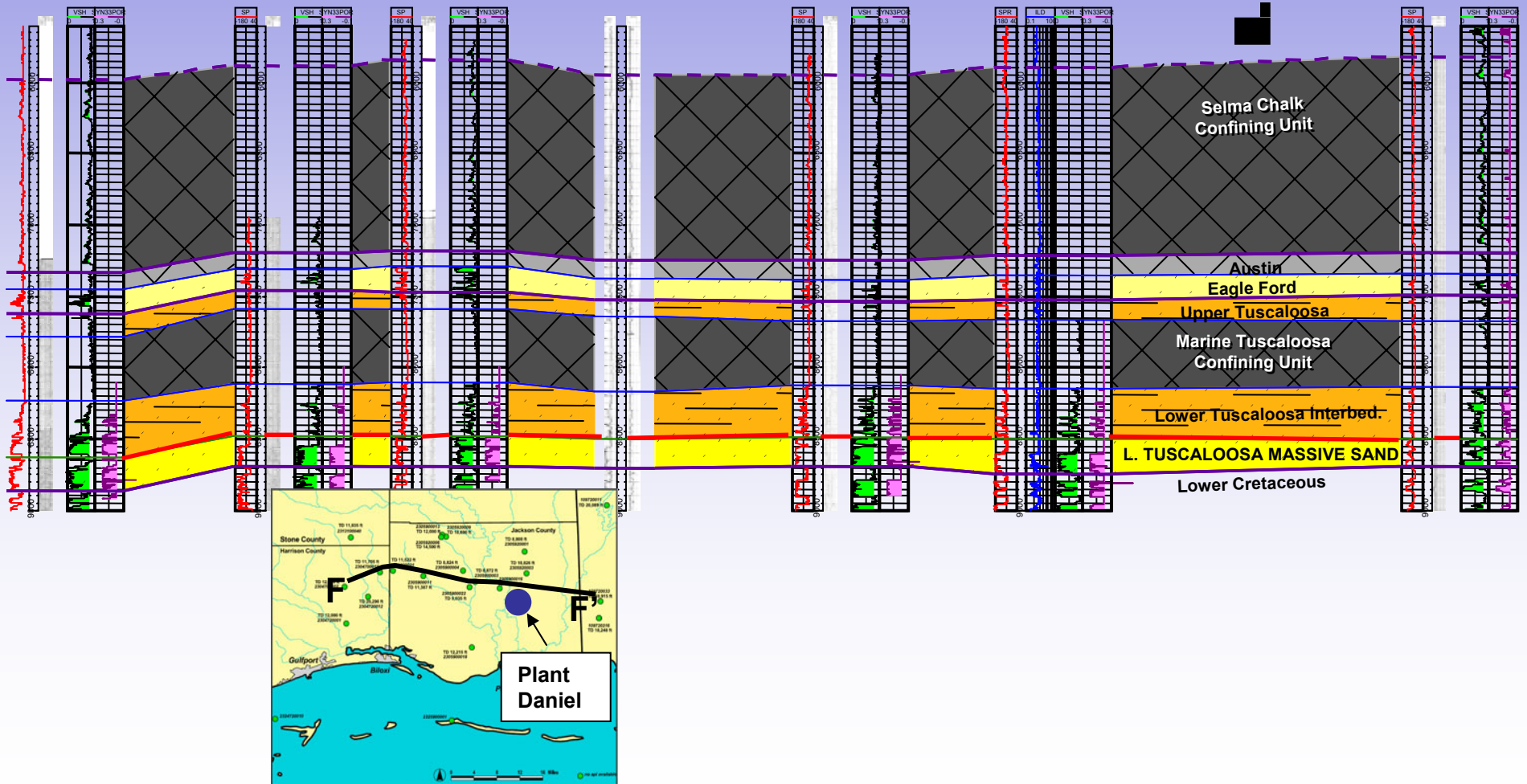


West-East Geologic Cross Section

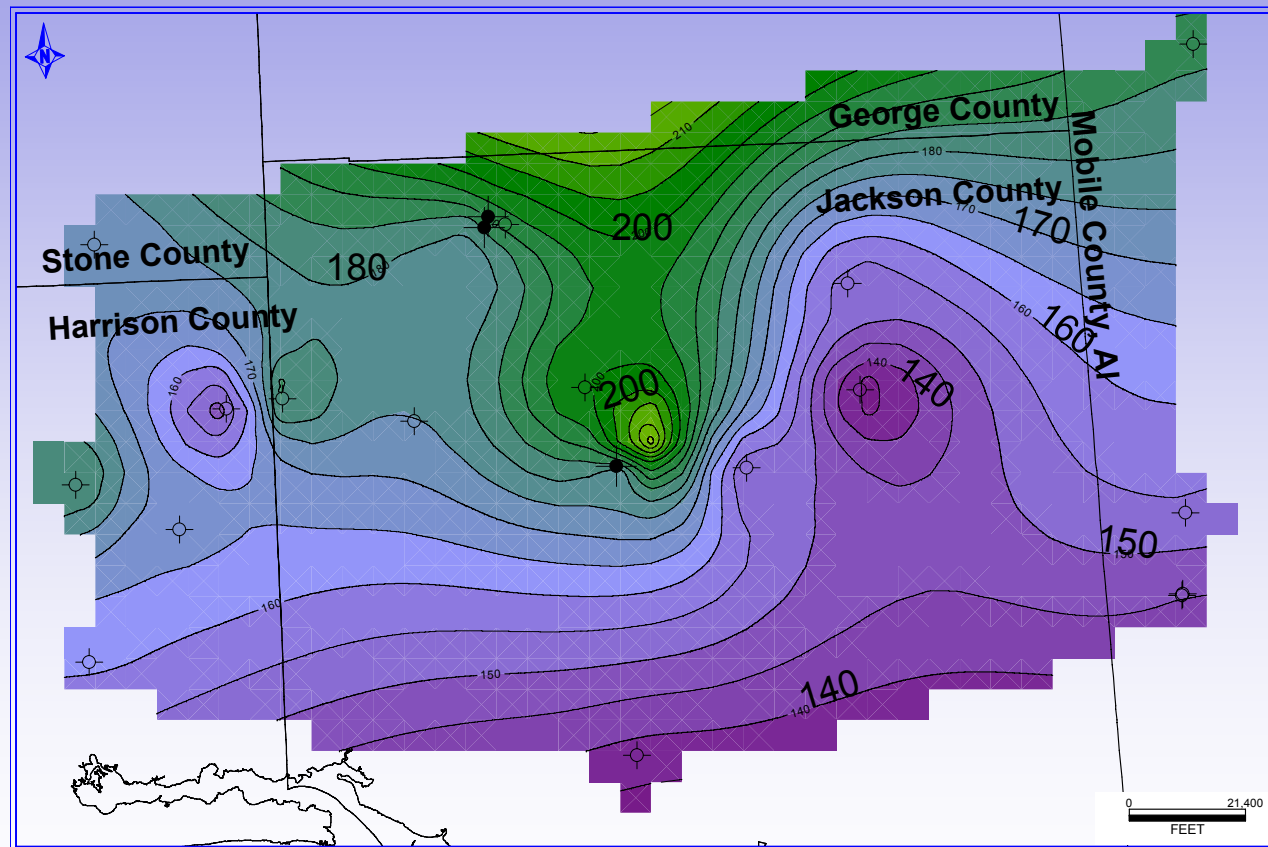
F(W)

F'(E)

Plant
Daniel



Net Sand Thickness Lower Tuscaloosa Massive Sand Unit



Modeling Assumptions

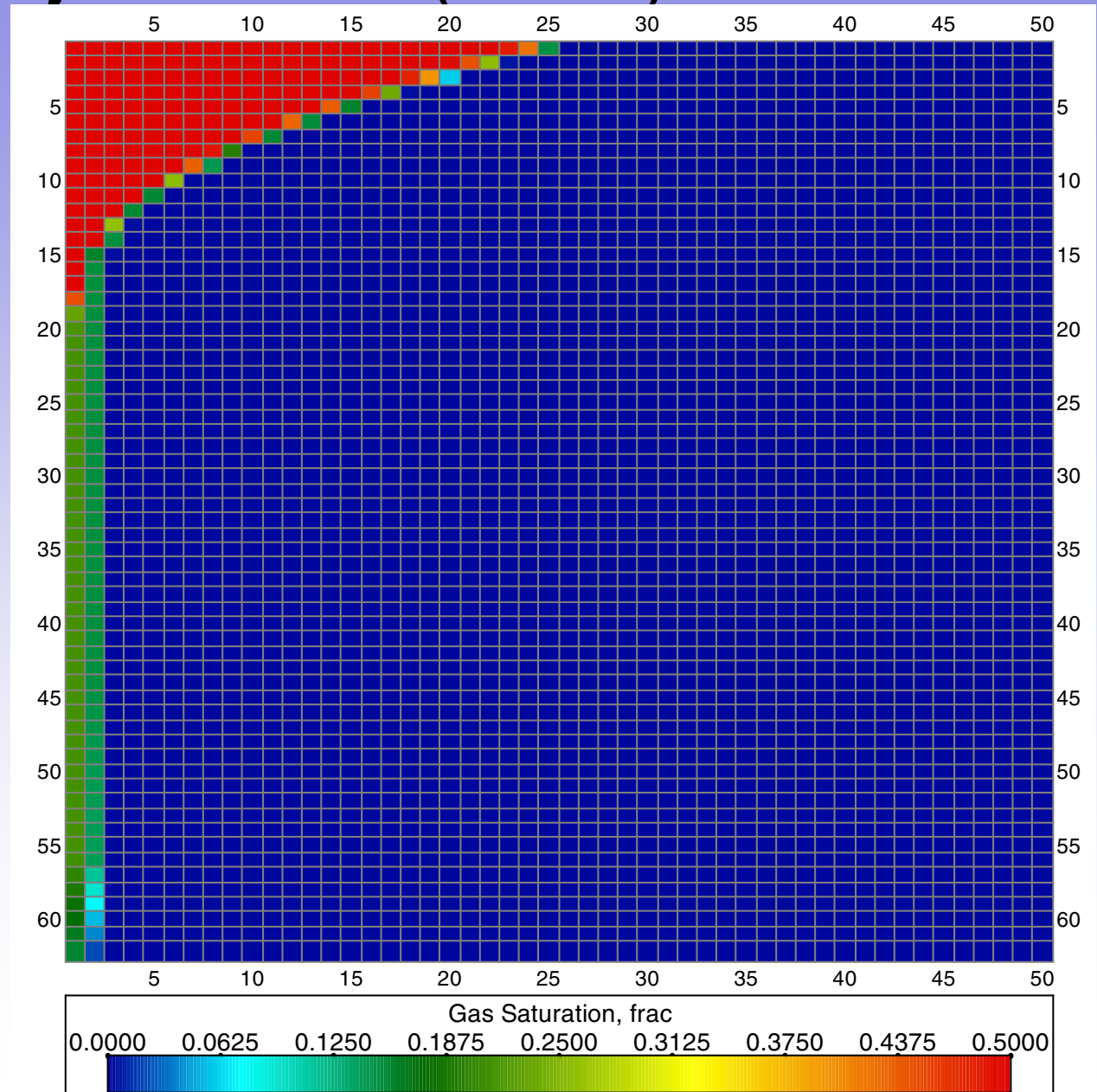
Thickness	Sand	187 ft
	Shale	77 ft
Porosity	Sand (from logs)	20% - 23%
	Shale (assumed)	5%
Water Saturation		100%
Salinity		200,000 ppm
Pressure		0.459 psi/ft
Temperature		229 °F
Dip		0°
Pore Volume Trapping		10%
CO2 Injection Volume		400,000 tonnes
Injection Duration		4 Years
Model Duration		100 Years

Data Modeling Indicates the Following Post-Injection Profile (4 Years)

100,000 Tons Per Year
CO₂ Injection in Lower
Tuscaloosa Massive Sand

Maximum plume extent at
the end of injection period
(4 years) is **2,500 ft**

One grid block = 100 ft
horizontally

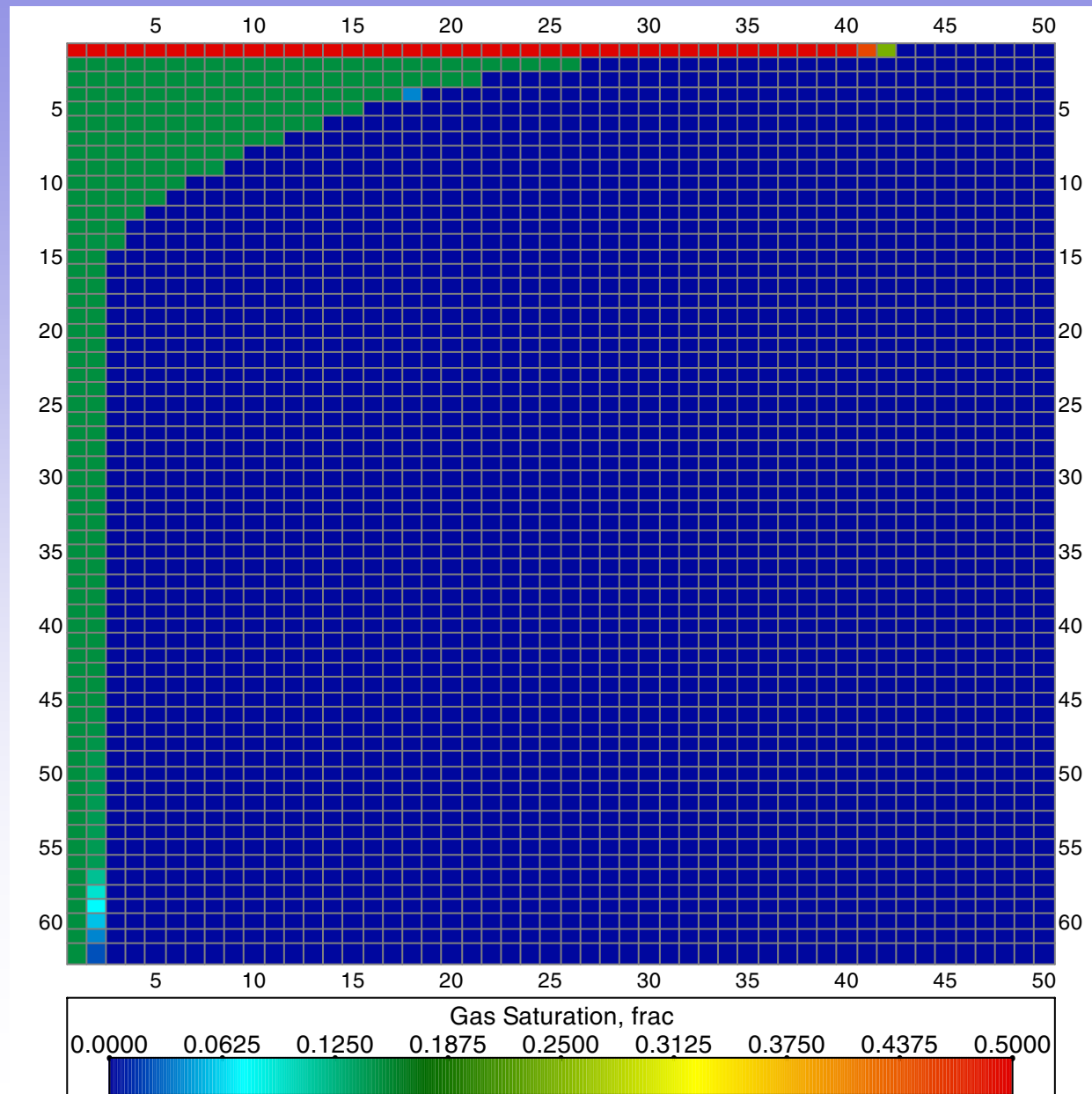


Data Modeling Indicates the Following Long-Term Profile (100 Years)

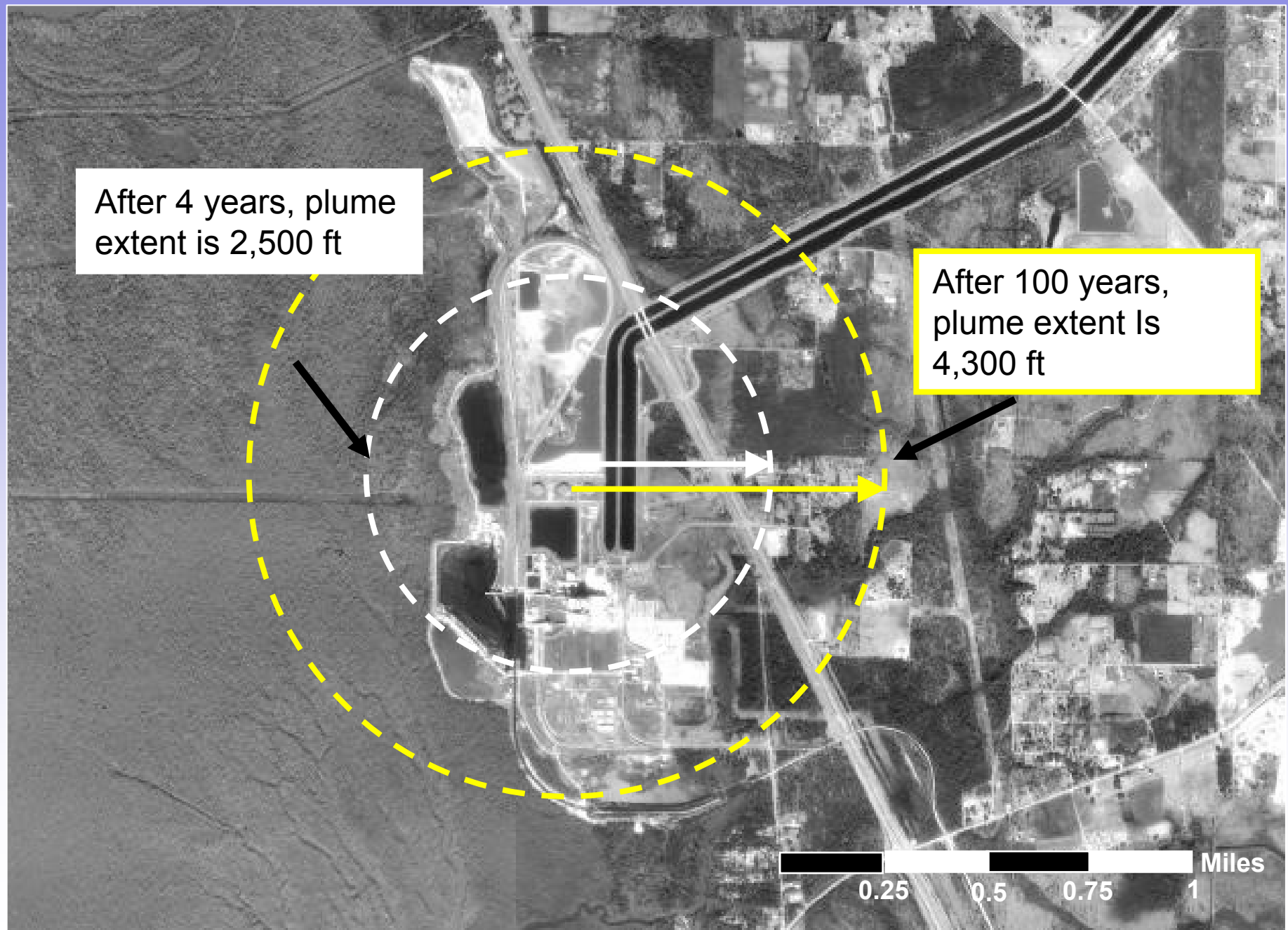
Maximum plume extent at the end of 100 years is **4,300 ft**

Key Finding:

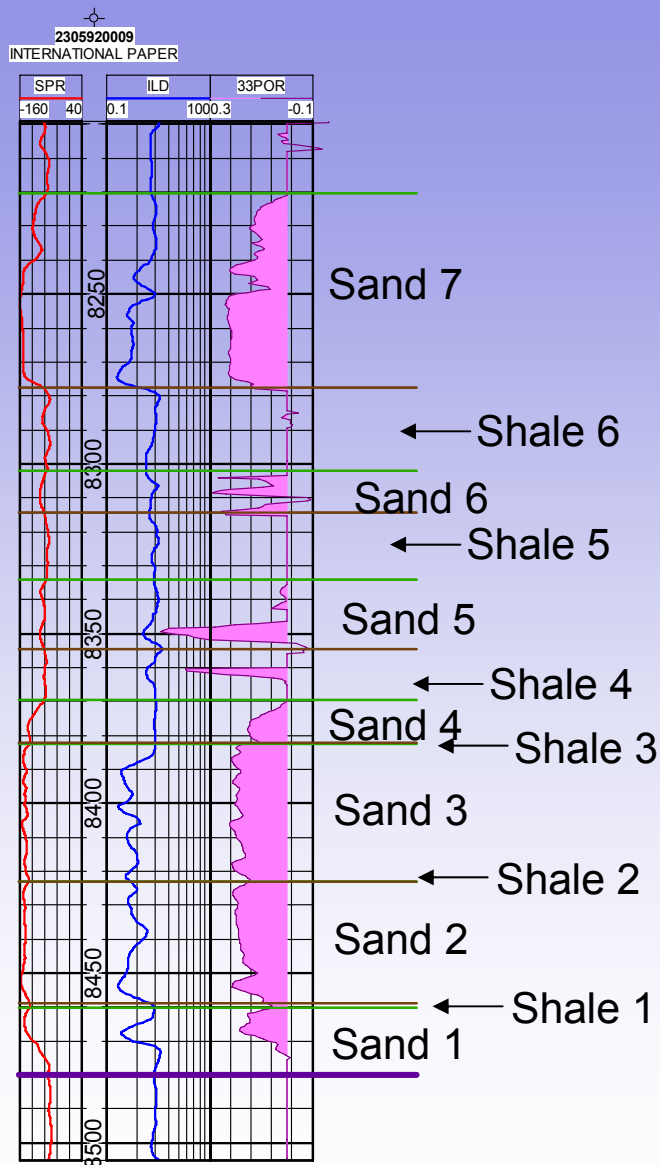
- Plume stretches an additional 1,800 feet horizontally along the top of the reservoir following the end of injection



Aerial Plume Extent



However, this isn't the whole story...



The previous materials have demonstrated that this formation may be an exceptional storage candidate.

The figure to the left is the Lower Tuscaloosa Massive Sand Unit type log in the vicinity of Plant Daniel.

Notice the Unit contains multiple sand packages that vary in thickness from 10 to over 50 ft, for a total net sand of about 190 ft, with by alternating shale breaks over a 300 ft total interval.

The architecture of these shale breaks may result in the baffling of the vertical migration of CO₂ creating multiple plumes that may ultimately migrate less distance horizontally than a plume in a single homogenous sand package.

Alternate Case #1. Injection into Massive Sand Interval With Shale Baffles Present

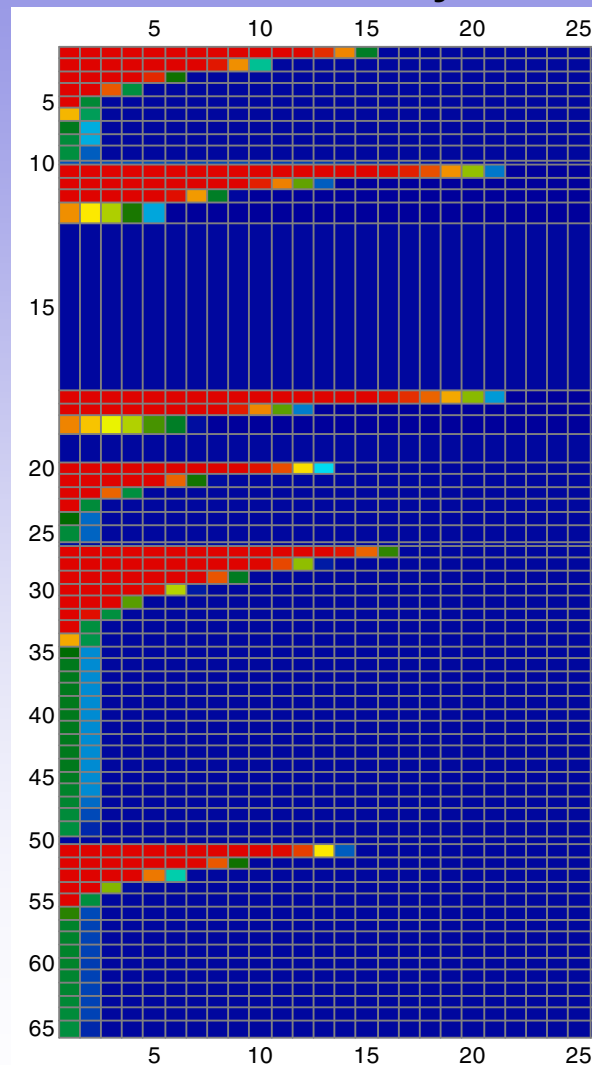
Maximum plume extent at
the end of injection period
(4 years) is **2,100 ft**

Maximum plume extent at
the end of 100 years is
2,400 ft

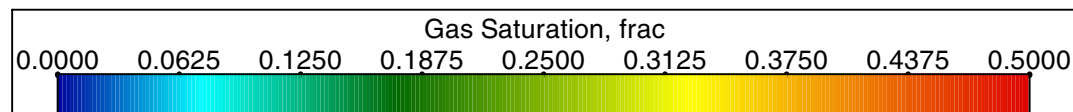
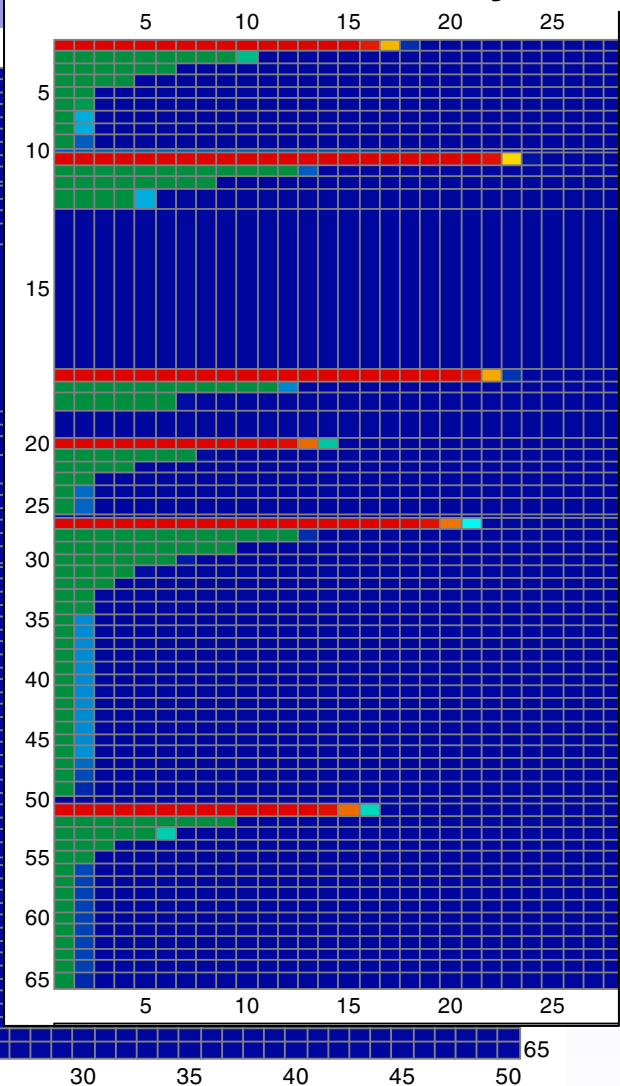
Key Findings:

- Plume stretches an additional 300 feet horizontally along the top of the reservoir after 100 years
- The presence of baffles decreases the plume extent by 1,900 ft versus the base plume model

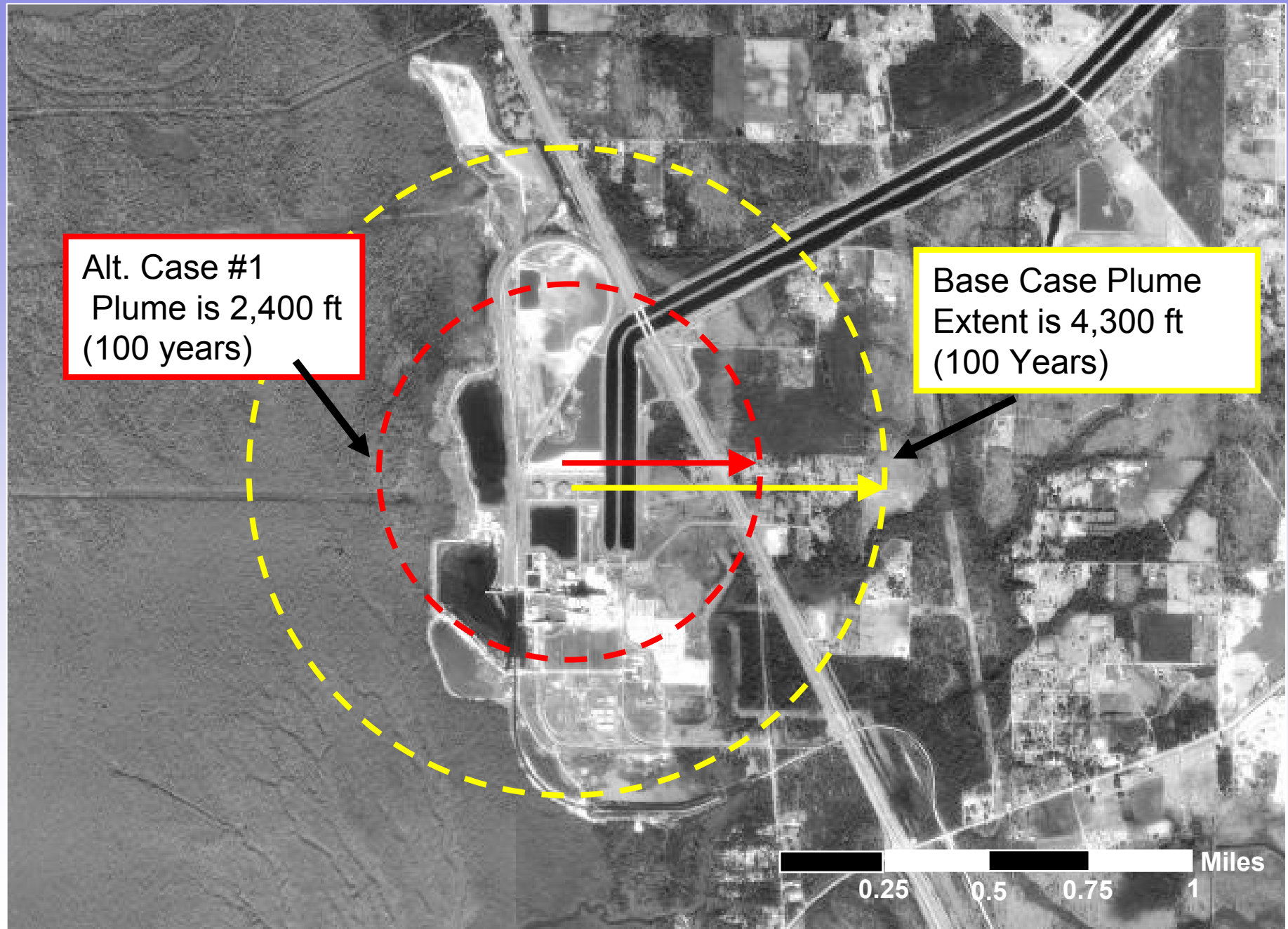
Plume extent after 4 years



Plume extent after 100 years



Shale Baffles Impact on Plume Extent



Alternative Case #2. Injection into Massive Sand Interval (with Baffles), 1% PVT

Run Alt. Case #1 (Massive Sand), decrease pore volume trapping by 90%

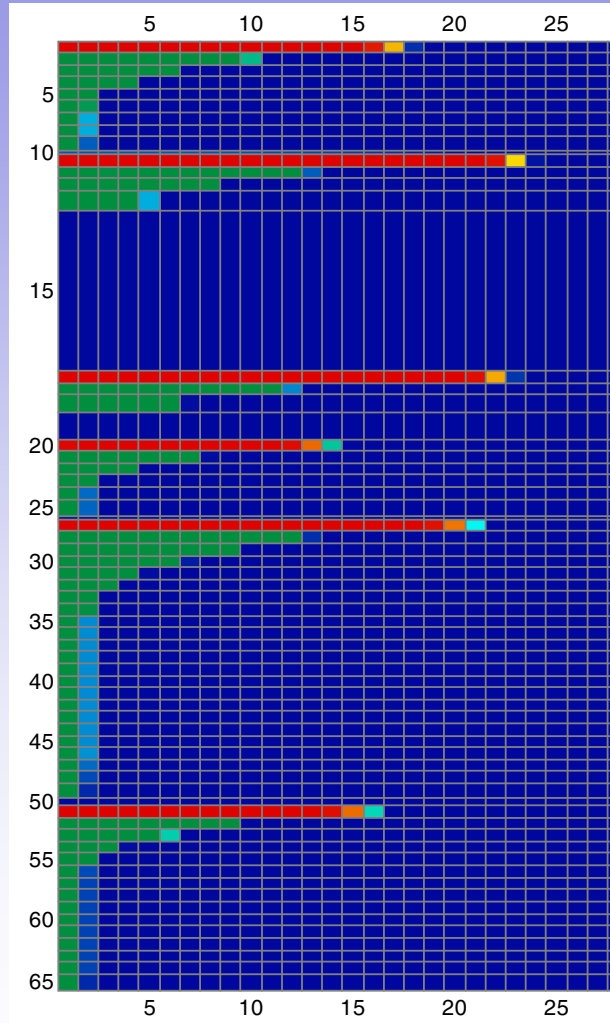
Maximum plume extent at the end of injection period (4 years) is **1,800 ft**

Maximum plume extent at the end of 100 years is **2,600 ft**

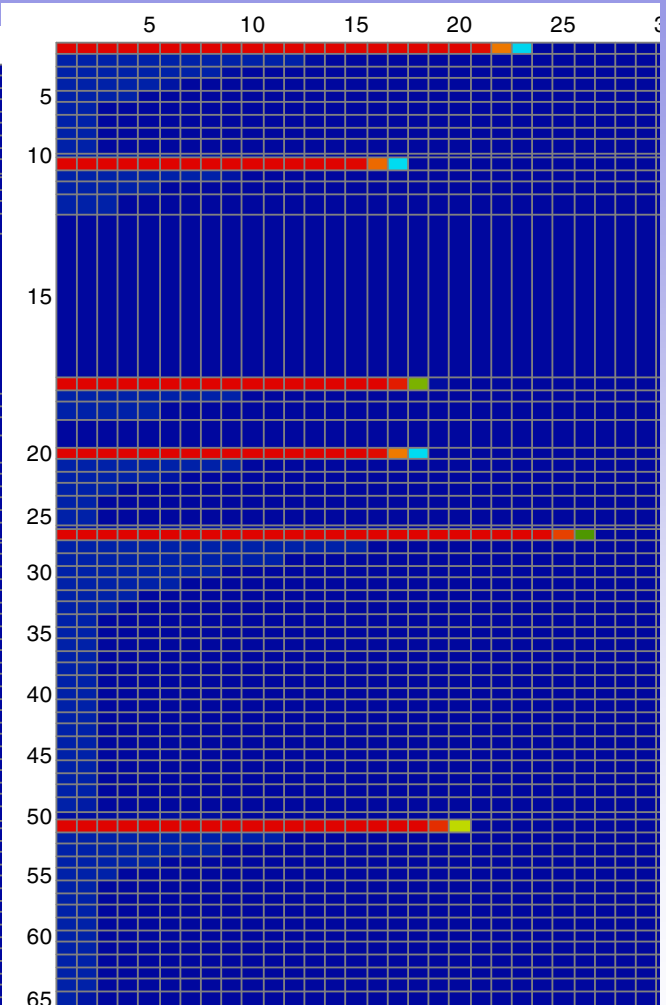
Key Finding:

- A small critical gas saturation increases plume extent by 200 ft versus Alt. Case #1

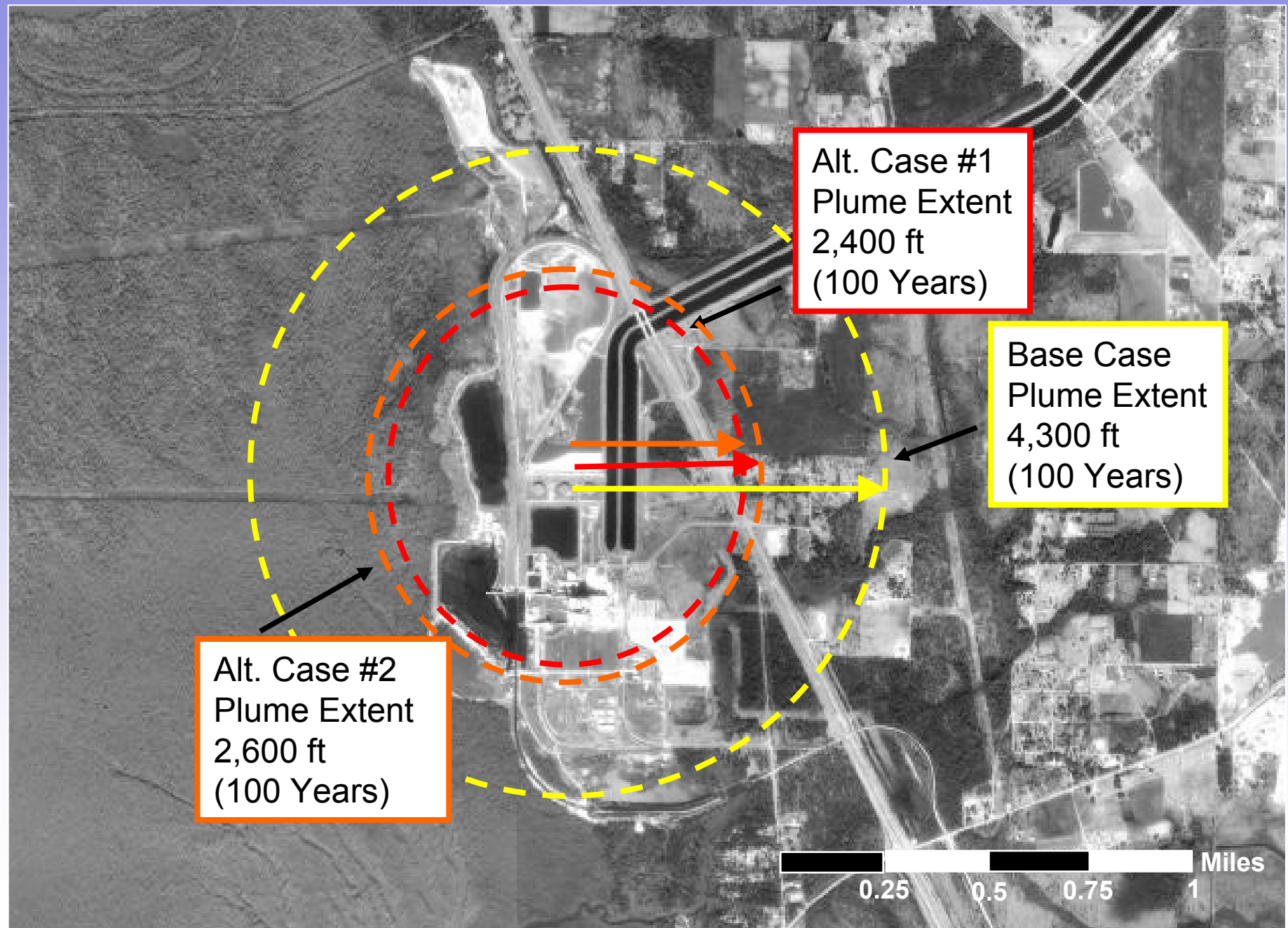
10% PVT plume after 100 yrs



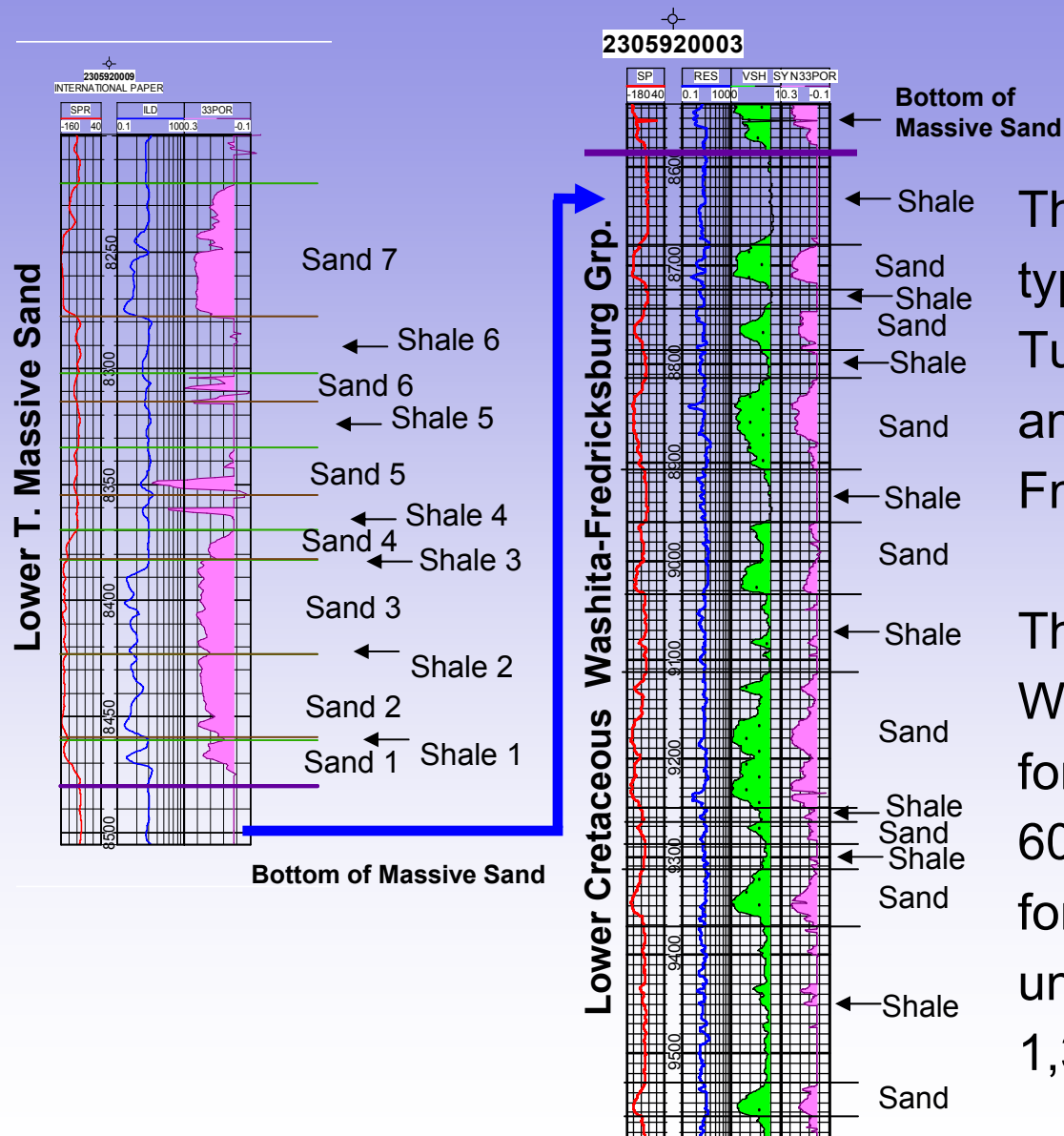
1% PVT plume after 100 yrs



Aerial Profile of Base Case and Alternative Cases #1 and #2



Alternate Case #3. Injection into Massive Sand and Lower Cretaceous Sands (with Baffles)



The figure to the left provides the type log for the Lower Tuscaloosa Massive Sand Unit and Lower Cretaceous Dantzler Fm. in Southern Mississippi.

The Massive Sand Unit and Washita-Fredricksburg formations together hold over 600 ft of net sand. These two formations contain multiple flow units and shale breaks over a 1,300 ft interval.

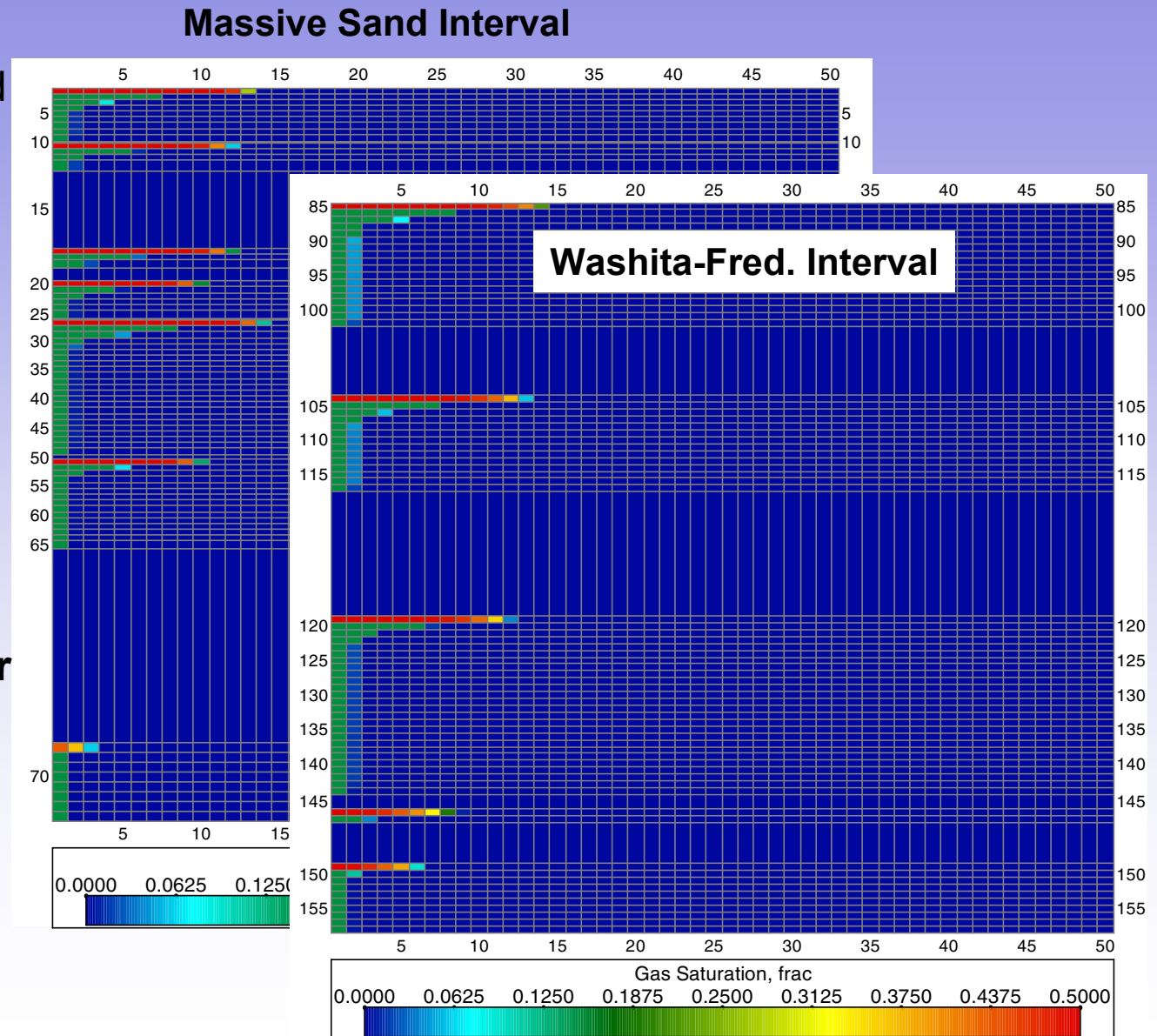
Alternate Case #3. Injection into Massive Sand and Lower Cretaceous Sands (with Baffles)

Maximum plume extent at the end of injection period (4 years) is **1,300 ft**

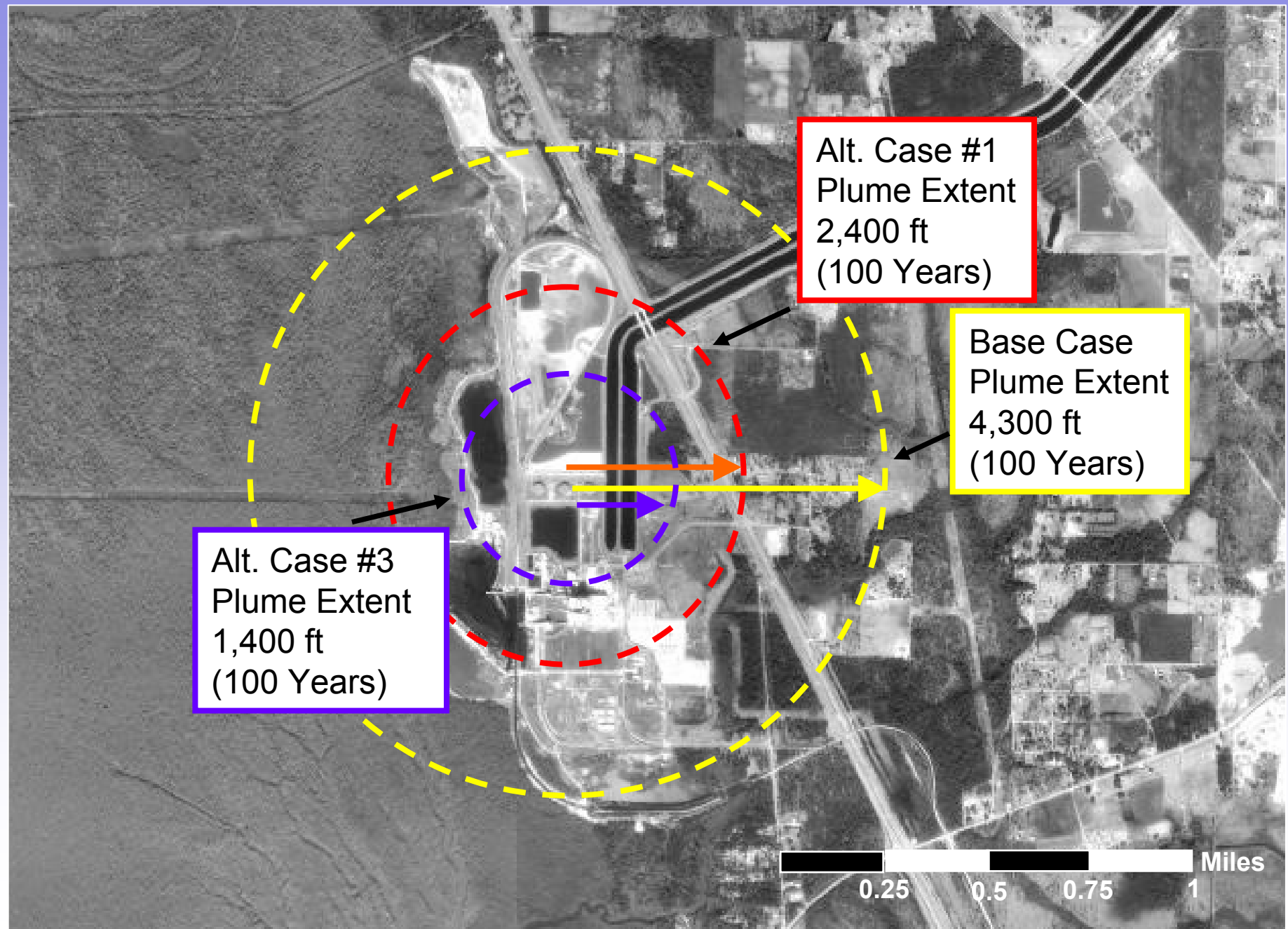
Maximum plume extent at the end of 100 years is **1,400 ft**

Key Findings:

- Plume stretches an additional 100 feet horizontally along the top of the reservoir after 100 years
- The presence of the additional injection interval decreases the plume extent by 1,000 ft versus the Massive Sand only (Alt. Case 1)



Aerial Profile of Base Case and Alternative Cases #1 and #3



Conclusions

- A storage reservoir's internal architecture can have a tremendous impact on its the ability to safely sequester CO₂.
- It is important to map the extent of the formation and its seals. However, equally important is understanding the internal interplay of the baffles and flow units in order to encourage plume immobilization.
- This understanding can have an impact on mineral rights required for storage, the injection strategy employed, the security of the plume, and, as a result, ultimate storage capacity and risk.